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13. ABSTRACT *(Maximum 200 words)*

TerraTherm Environmental Services, Inc. and RT Environmental Services, Inc. conducted a successful field demonstration of In-Situ Thermal Desorption (ISTD) sponsored by the Bay Area Defense Conversion Action Team Environmental Technology Partnership. The ISTD technology uses the direct application of heat supplied by electrical heater elements to raise the temperature of soil in-situ to destroy the organic contaminant targeted. Two configurations of the heating elements are the Thermal Blankets, which treat surface soil up to 18 inches deep, and the Thermal Wells, which are drilled vertically or horizontally to treat deep or hard-to-reach areas. Both ISTD configurations were demonstrated at Mare Island Shipyard in Vallejo, California.

The advantages of TerraTherm's ISTD technology provides benefits not found in conventional remediation techniques that outweigh the limitations. The goals of the demonstration were to gain further evidence on the performance of ISTD to destroy and remove PCB's to well below 2mg/kg and to obtain cost estimate data. Verification sampling results showed that TerraTherm met the 2 mg/kg goal by achieving non-detect readings in all areas tested. Continuous air monitoring from the stack showed all emissions within allowable limits, as was ambient HC1 levels. The project was concluded in November 1997. Previous demonstrations of ISTD have been conducted at a PCB contaminations at a state superfund site in New York and a federal superfund site in Missouri, and a chlorinated solvent contamination site in Indiana. The cost of ISTD depends on a variety of factors such as depth of contamination, soil moisture, and contaminant types.

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In-Situ Thermal Desorption (ISTD), PCB's, organic contaminants, remediation, thermal blankets, thermal wells, chlorinated solvents, pesticides, and petroleum wastes.

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TechData Sheet

Naval Facilities Engineering Service Center
Port Hueneme, California 93043-4370

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Destruction of PCB's in Contaminated Soils at Mare Island Shipyard

A Demonstration of In-Situ Thermal Desorption

Conducted by:
TerraTherm Environmental Services, Inc., The Woodlands, TX and
RT Environmental Services, Inc., King of Prussia, PA

In cooperation with:
Bay Area Defense Conversion Action Team Environmental Technology Partnership

Introduction

TerraTherm Environmental Services, Inc. (a subsidiary of Shell Technology Ventures, Inc., Houston, TX) and RT Environmental Services, Inc. conducted a successful field demonstration of In-Situ Thermal Desorption (ISTD) sponsored by the Bay Area Defense Conversion Action Team Environmental Technology Partnership (BADCAT ETP). The ISTD technology uses the direct application of heat supplied by electrical heater elements to raise the temperature of soil in-situ to destroy the organic contaminant targeted. Two configurations of the heating elements are the Thermal Blankets, which treat surface soil up to 18 inches deep, and the Thermal Wells, which are drilled vertically or horizontally to treat deep or hard-to-reach areas. Both ISTD configurations were demonstrated at Mare Island Shipyard in Vallejo, California on soils contaminated with polychlorinated biphenols (PCBs). All post-treatment samples had non-detectable PCB concentrations (less than 0.033 mg/kg).

The BADCAT ETP facilitates the selection, demonstration, and validation of innovative environmental technologies to expedite cleanup and conversion of closing military bases. The public-private partnership includes the Bay Area Economic Forum, Bay Area Regional Technology Alliance, California Environmental Protection Agency, U.S. Environmental Protection Agency, U.S. Navy, Chevron Research and Technology Company, San Francisco State University Center for Public Environmental Oversight, and other technical experts. TerraTherm's ISTD technology was selected by the partnership for demonstration. The goals were to gain further evidence on the performance of ISTD to destroy and remove PCBs to well below 2 mg/kg and to obtain additional cost estimate data.

Advantages and Limitations of ISTD

TerraTherm's ISTD technology provides benefits not found in conventional remediation techniques:

- Fast in-situ removal or destruction of a mix of volatile and semi-volatile organics to very low residual levels
- Contaminant molecules destroyed in-situ and collected or destroyed in a vapor treatment facility - carbon dioxide and water vapor are virtually the only air emissions
- Works in unsaturated and saturated zones, in surficial and deeper contaminated zones, and in heterogeneous soils including low-permeability clays
- Can operate under and next to roads, structures, foundations and other heavy, fixed installations
- Can operate at any depth achievable by standard drilling techniques
- Low profile operations – quiet and odorless
- Lowers long-term liability exposure by completely destroying contaminants on-site

The following are limitations of the ISTD technology:

- May not be cost effective for smaller sites
- Underground utilities, such as electrical and gas lines, could be damaged if too close to the heaters or hot soil
- Dewatering may be required if the treatment zone is below the water table and hydraulic conductivity is low

System Description

The heating technology was developed in Shell Research Labs over the last 25 years as part of its enhanced oil recovery efforts. TerraTherm has developed two configurations of the heating elements for ISTD: Thermal Blankets and Thermal Wells. ISTD will destroy volatile and semi-volatile organic compounds, including PCB's, chlorinated solvents, pesticides, and petroleum wastes. Shown in Figure 1 is a conceptual layout of the TerraTherm treatment system and auxiliary components. Figure 2 shows a block diagram of the treatment train.

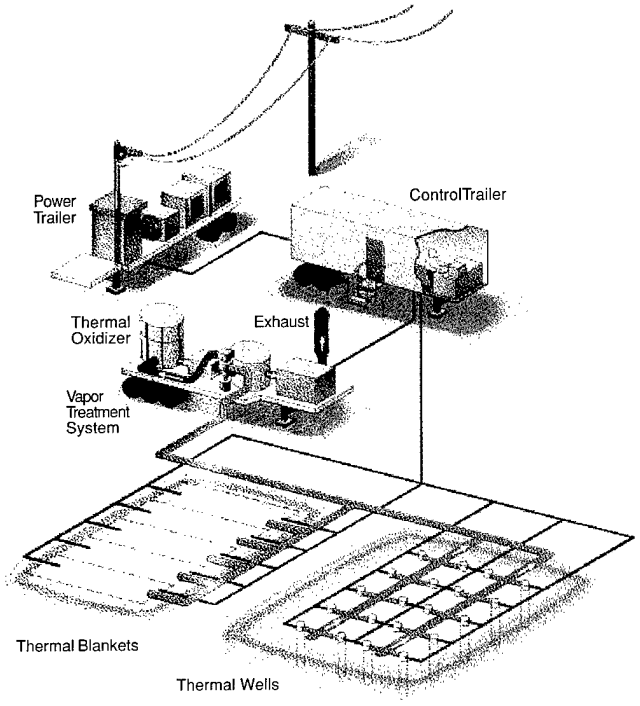

Figure 1. TerraTherm treatment system.

The Thermal Blanket works like a large electric blanket and a powerful vacuum cleaner. Thermal Blankets, used for surficial contamination, work up to depths of 18 inches.

Typically, each blanket is made up of an 8- by 20-foot steel box. Stainless steel webbing is suspended from the bottom of each box. Heated element rods are threaded through the webbing to transfer heat into the soil below the blanket. Several Blankets set up side-by-side increase the total area treated at one time. Contaminants are vaporized by heating the soil with the blanket. Vapors are drawn out of the soil and through the blanket by means of a vacuum system. The Blankets are sealed and under negative pressure so that vapors do not escape. Most contaminants are destroyed in the extremely hot soil near the heat source. When destroying PCBs, soil temperatures must reach 600°F and heating elements are set between 1,400°F and 1,600°F. Remaining vapors are cleaned in the trailer-mounted Vapor Treatment System, which includes a flameless thermal oxidizer and activated carbon filters.

The flameless thermal oxidizer uses a ceramic matrix heated to 1,800°F, which ensures thorough mixing, uniform temperature and consistent residence time. This is in contrast to flame-based systems, which may create products of incomplete combustion due to the variable nature of vapor flow through the flame zone. Use of the flameless thermal oxidizer results in extremely high destruction efficiency for off-gas vapors. As a result, there are virtually no products of incomplete combustion emissions. Vapors are cooled in a heat exchanger after leaving the thermal oxidizer and before entering a carbon adsorber. Continuous monitoring and a carbon adsorber ensure that the resulting emissions contain only carbon dioxide and water vapor.

Thermal Wells use the same process as Thermal Blankets, except that heating elements are placed in wellbores drilled on a regular pattern. Typical Well spacings can be seven to ten feet. Wells can be drilled vertically into the contaminated zone, possibly as deep as several hundred feet. They may reach horizontally under operating facilities, roadways and through concrete and other structures. Simulations suggest that thermal wells can work both above and below the water table. Treatment of the saturated zone can be achieved by dewatering the treatment zone, which can be achieved by pumping, or by boiling off the water with the Thermal Wells if the hydraulic conductivity is low.

Remediation levels and cleanup times can be predicted by computer simulation before the project begins. Monitoring systems and thermocouple probes in the soil are used to measure the progress of the thermal front through the soil. Experience has shown that there is good agreement between the computer predictions and actual results. Pre- and post-treatment samples are used to verify the treatment.

Usually, the very low residual organic contaminants remaining in the soil after treatment are significantly lower than typical state and federal cleanup levels. In comparison with other technologies, contaminant destruction by in situ thermal desorption is quite complete.

When PCBs and other halogenated hydrocarbons are destroyed, hydrochloric acid is produced as shown in Figure 3. The acid is stabilized rapidly by precipitation with natural soil elements, principally iron. For example, hydrochloric acid and iron will form iron chloride, which is harmless and very stable. Experience remediating PCBs shows that acid gas emissions typically are very low.

Because this is a thermal process, the treatment of chlorinated organics increases the possibility of dioxin and furan formation. ISTD vaporizes and destroys dioxins and furans at rates faster than they are created. Analysis of post-treatment soil samples shows toxic equivalent concentration levels below the background level of 0.008 µg/kg for uncontaminated soils.

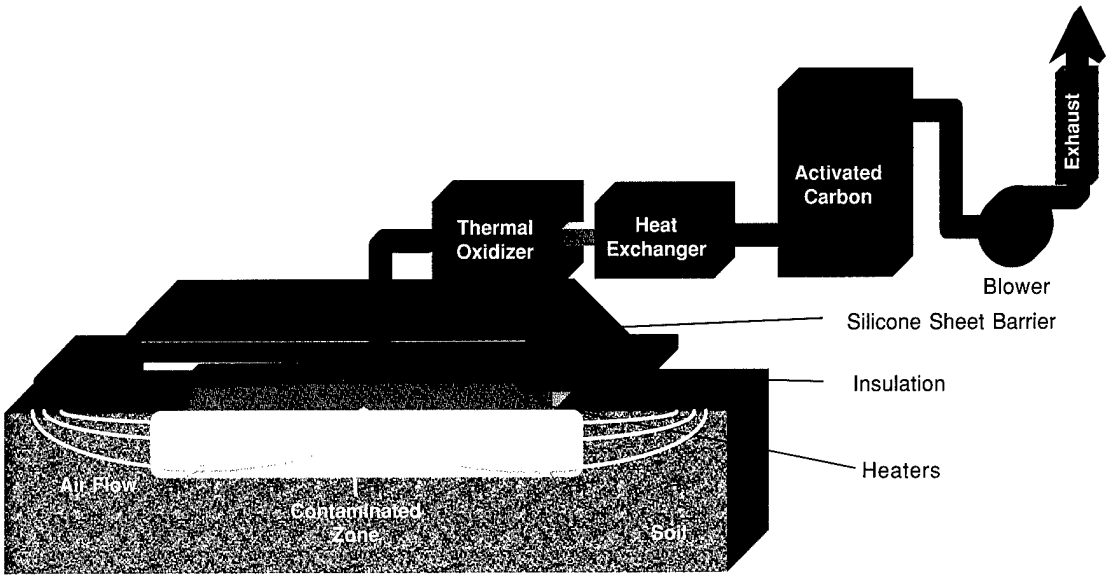

Figure 2. TerraTherm treatment system schematic.

Mare Island Shipyard Demonstration

The field demonstration was conducted adjacent to a former electrical shop within Installation Restoration Site 11 at the Mare Island Shipyard. Previously at this site, transformers, using oil containing polychlorinated biphenols (PCBs), were washed out. The liquid waste was pumped to a grease trap prior to discharge to the industrial wastewater collection system. The grease trap was subsequently removed and back filled with soils contaminated with PCBs. Levels as high as 2,200 mg/kg were identified at the site during the Remedial Investigation.

The demonstration began in August 1997 with an expedited air permit from the California EPA. Twelve Thermal Wells, spaced at approximately 5-foot centers, were set to an operational depth of 14 feet within the former grease trap area. Pre-treatment sampling showed an average PCB concentration of 54 mg/kg in the 300 ft^2 area. Groundwater was not encountered during installation of the Wells.

In another area, two Thermal Blankets were used to remediate the top 12 inches of a 320 ft^2 test area in the parking lot next to the electrical shop. This soil was impacted by the release of an oily sludge with a total PCB concentration of 24,000 mg/kg. The pre-treatment average PCB concentration of this soil was 21 mg/kg. Soil composition in both test areas was mixed since it included a considerable amount of backfill.

The Thermal Wells and Blankets were operated separately. Soil temperatures were raised to 600°F with heaters set between 1,400°F and 1,600°F. The Thermal Wells operated for 35 days and the Thermal Blankets operated for 5 days until soil temperatures reached 600°F. The heaters were then kept energized for an additional 48 hours. The MU 125 (Mobile Unit-125 cfm), which contains the flameless thermal oxidizer gases. An emergency electrical generator was used to keep critical process equipment operating in case of a disruption to electricity.

Verification sampling results showed that TerraTherm met the 2 mg/kg goal by achieving non-detect readings (< 0.033 mg/kg) in all areas tested. Continuous air monitoring from the stack showed all emissions within allowable limits, as was ambient HCl levels. The project was concluded in November 1997.

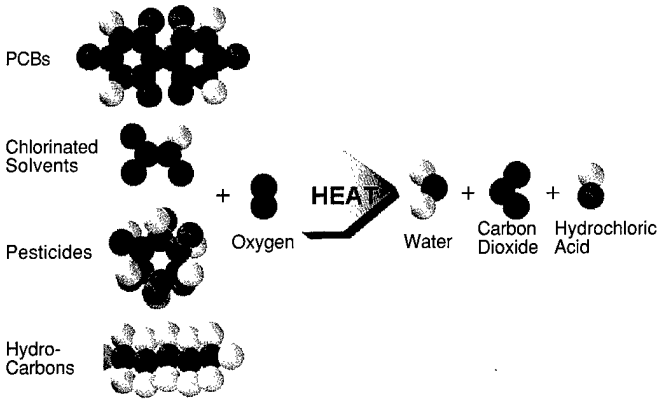

Figure 3. Treatment chemistry.

Previous Demonstrations of ISTD

PCB Contamination at a State Superfund Site in New York

TerraTherm's ISTD remediation was employed at a former drag strip containing PCB contamination as high as 5,000 mg/kg at depths from 6 to 18 inches. Thermal Blankets treated the 5,000 square feet area and the soil cleanup target level of less than 2 mg/kg was achieved. Soil temperatures ranged from 480°F to 840°F during the ten-day remediation operation. Air emissions were well below New York and EPA regulatory limits and there was virtually no dust or odors.

PCB Contamination at a Federal Superfund Site in Missouri

Working in tight clay soil, TerraTherm used ISTD to reduce PCBs to below 2 mg/kg at a former motor and transformer repair and sales shop. Thermal Blankets treated initial PCB concentrations of 510 mg/kg up to 6 inches deep and 3 mg/kg from 6 to 18 inches deep. Sixteen Thermal Wells reaching ten feet deep operated at temperatures up to 1,900°F and reduced PCB concentrations from as high as 19,900 mg/kg. Representatives from US EPA and the Missouri Department of Natural Resources monitored the demonstration.

Chlorinated Solvent Contamination at a Site in Indiana

Fifteen Thermal Wells treated a 30- by 30-foot area with 1,1-dichloroethylene (DCE) contamination levels up to 650 mg/kg at depths to 12 feet. The wells were heated to 1,500°F and the temperature of the soil in between the wells exceeded 250°F. Because DCE is much more volatile than PCBs, the lower temperatures are sufficient. The remediation objective of 80 mg/kg was easily met according to preliminary sampling. All but one area had non-detectable quantities of the contaminant (1 to 3mg/kg) with the single exception at only 9 mg/kg.

Cost for Soil Remediation

The cost of In Situ Thermal Desorption depends on a variety of factors such as depth of contamination, soil moisture, and contaminant types. In general, In Situ Thermal Desorption would be cost-competitive for TSCA and RCRA wastes with alternative processes, since excavation, hauling, backfilling and off-site disposal or incineration would not be required. Also, in many industrial and utility applications, remediation could usually be completed with minimal disruption to ongoing operations, reducing the overall cost impact.

TerraTherm's optimal projected ISTD treatment costs range from $100 per ton for a 10,000-ton site to $250 per ton for a 1,000-ton site. Cleanup of a very small Navy PCB site (less than 1,000 tons) using ISTD was estimated to cost approximately $500 per ton in 1998. In addition to the site factors mentioned in the above paragraph, the main contribution to the determination of cost is the size of the site or the economy of scale. Smaller sites (less than 2,000 cubic yards) will be on the high end and those with contamination less than 3 feet will contribute to higher costs since the heat loss at the surface where blankets are used is significant. Larger, deeper, and drier sites where the wells operate will be at the low end of the cost structure. A low-cost pilot test using TerraTherm's Mobile Demonstration Unit could be performed on site to provide process efficiency and cost estimates.

For more information about In Situ Thermal Desorption or BADCAT ETP, contact:

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